Title: Finite Element Analysis of E906 Station 3 & 4 Detector Support Structure at Fermilab		
Calculation No.: **NE-EO-2011-0XX**		Revision Number: 0

CALCULATION COVER SHEET

Supersedes Calculation No.:	Total Number of Attachments:
Analyzed System: E906 Station 3 & 4 Drop Connectors and Service Beam Support Structure	
Purpose of Revision: Initial Issue	

PREPARER

P. Strons & R. Fischer, NE-EO

Print Name	Signature	Date

REVIEWER

Print Name	Signature	Date

VENDOR APPROVER (if vendor-supplied calculation)

n.a.

Print Name	Signature	Date

FINAL APPROVER

Print Name	Signature	Date

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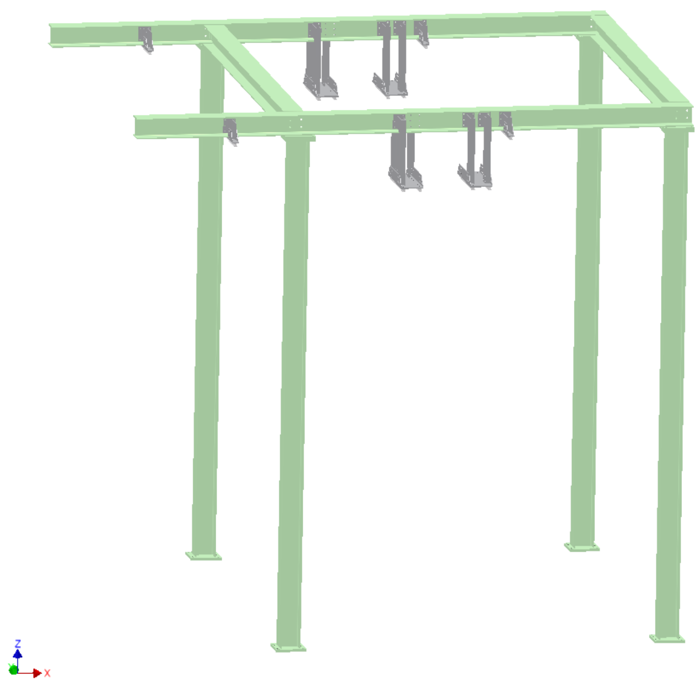

Figure 1 E906 Station 3 &4 Support Frame structural members (shown in light green) are AISC size W8x31 wide-flange I-beams. The drop connectors (shown in gray) connect the detectors to the structure.

1 Objectives

The purpose of this note is to document the FEA confirming that the design of E906 Stations 3 & 4 Support Frame (see Figure 11) meets requirements of Allowable Strength Design (ASD) as defined by The AISC Steel Construction Manual, 13th Edition.

2 Limitations

This analysis is limited to the Support Frame structure. The analysis is contingent upon the use meeting the assumptions specified in section 5.

3 Acceptance Criteria

The acceptance criteria are to meet the requirements of the AISC Steel Construction Manual 13th Edition, using ASD. The requirements are defined in Part 16, Specifications and Codes.

4 Methodology

The methodology of calculation was based on static elastic FEA, which was verified by following the AISC Steel Construction Manual code to determine the allowable loading in the structure.

5 Assumptions

The following assumptions are made with regard to the construction of the Support Frame structure:

- The material used for construction of the structure is A36 steel with linear elastic behavior
- The A36 steel has a Young's Modulus of 29e6 psi and poisson's ratio of 0.30
- The design of the Support Frame structure is described by the file Station_3_and_4_Layout_for Kevin.stp.

5.1 Support Frame applied loads

There are three load cases in this FEA:

- Load Case #1 models the detectors in place plus gravitational loading from the mass of the structural members (See Fig. 2)
- Load Case #2 models the effect of moving detectors out for service plus gravitational loading from the mass of the structural members (See Fig. 3)
- Load Case #3 has the loads from Load Case #1 plus an additional seismic load (See Fig. 4)

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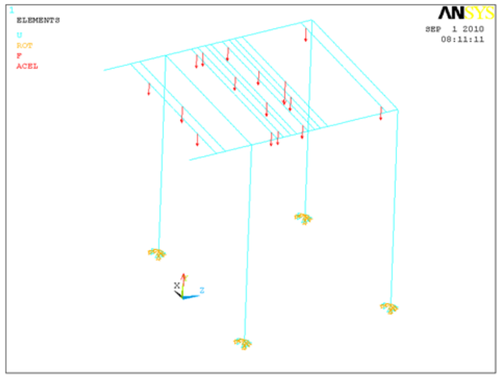
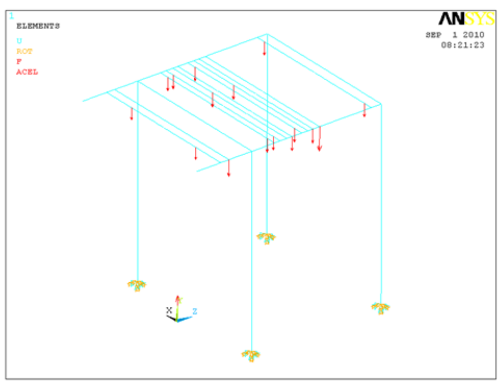
Load Case #1
•Detectors In Place
•Gravity Load



	CAD_load Xeast	CAD_load Xwest	Cross Beam No.	CAD_load_z	Total Weight	Detector Type
Chamber 3 Lower			1	-44.403		
Chamber 3 Upper	-48.629	48.629	2	-16.773	770	fixed
Hodo 3x	-46.5	46.5	3	-7.31	540	sliding
Iron Wall	0	0	4	19.6	0	
Station 4a prop tube X	-75	75	5	46.06	870	fixed
Station 4a Prop tube Y	-75.5	75.5	6	52.68	870	fixed
Station 4Ya1 Hodo	-15	67.25	7	60.44	450	sliding
Station 4Ya2 Hodo	-67.25	15	8	66.31	450	sliding
Station 4bx Prop tubes	-75	75	9	78.06	870	fixed
Station 4BY1 Hodo	-15	67.25	10	84.88	450	sliding
Station 4BY2 Hodo	-67.25	15	11	90.75	450	sliding
Stations 4BX Hodo	-62.5	62.5	12	98.5	775	sliding
Station 4by Prop tubes	-75.5	75.5	13	159	870	fixed

Figure 2

Load Case #2
•Detectors Rolled Out.
•Gravity Load



	CAD_load Xeast	CAD_load Xwest	Cross Beam No.	CAD_load_z	Total Weight	Detector Type
Chamber 3 Lower			1	-44.403		
Chamber 3 Upper	-48.629	48.629	2	-16.773	770	fixed
Hodo 3x	-46.5	46.5	3	-7.31	540	sliding
Iron Wall	0	0	4	19.6	0	
Station 4a prop tube X	-75	75	5	46.06	870	fixed
Station 4a Prop tube Y	-75.5	75.5	6	52.68	870	fixed
Station 4Ya1 Hodo	-15	67.25	7	60.44	450	sliding
Station 4Ya2 Hodo	-67.25	15	8	66.31	450	sliding
Station 4bx Prop tubes	-75	75	9	78.06	870	fixed
Station 4BY1 Hodo	-15	67.25	10	84.88	450	sliding
Station 4BY2 Hodo	-67.25	15	11	90.75	450	sliding
Stations 4BX Hodo	-62.5	62.5	12	98.5	775	sliding
Station 4by Prop tubes	-75.5	75.5	13	159	870	fixed

Figure 3

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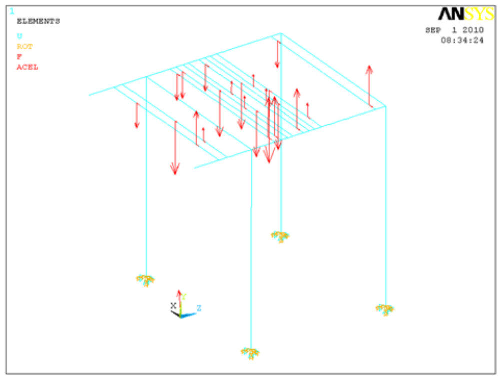
Load Case #3
•Detectors In Place.
•Gravity Load
•Seismic X Load



	CAD_load Xeast	CAD_load Xwest		CAD_load_ z	Total Weight		Seismic Loads			
Chamber 3 Lower			1	-44.403			Ly	Ry	Lx	Rx
Chamber 3 Upper	-48.629	48.629	2	-16.773	770	fixed	444	326	57.75	57.75
Hodo 3x	-46.5	46.5	3	-7.31	540	sliding	168	-708	40.5	40.5
Iron Wall	0	0	4	19.6	0					
Station 4a prop tube X	-75	75	5	46.06	870	fixed	520	350	65.25	65.25
Station 4a Prop tube Y	-75.5	75.5	6	52.68	870	fixed	519	351	65.25	65.25
Station 4Ya1 Hodo	-15	67.25	7	60.44	450	sliding	158	-608	33.75	33.75
Station 4Ya2 Hodo	-67.25	15	8	66.31	450	sliding	158	-608	33.75	33.75
Station 4bx Prop tubes	-75	75	9	78.06	870	fixed	520	350	65.25	65.25
Station 4BY1 Hodo	-15	67.25	10	84.88	450	sliding	158	-608	33.75	33.75
Station 4BY2 Hodo	-67.25	15	11	90.75	450	sliding	158	-608	33.75	33.75
Stations 4BX Hodo	-62.5	62.5	12	98.5	775	sliding	182	-957	58.125	58.125
Station 4by Prop tubes	-75.5	75.5	13	159	870	fixed	519	351	65.25	65.25

Figure 4

6. Calculation

6.1 FEA Load Case #1 Results

Load Case #1 is the standard configuration with loading applied from each detector. In Fig. 5, the bending stress combined with the direct stress is shown in psi. The maximum combined stress (2139 psi) is in the W8X31 beams located at the top on either side of the beamline. The minimum stress is found in the same beams with a value of -2241 psi.

In Fig. 6, the deflection in the vertical direction is shown. The ends of the W8X31 beams on the sides deflect up by 0.016 inches. Near the midpoint of the same beams, the deflection is down by 0.044 inches.

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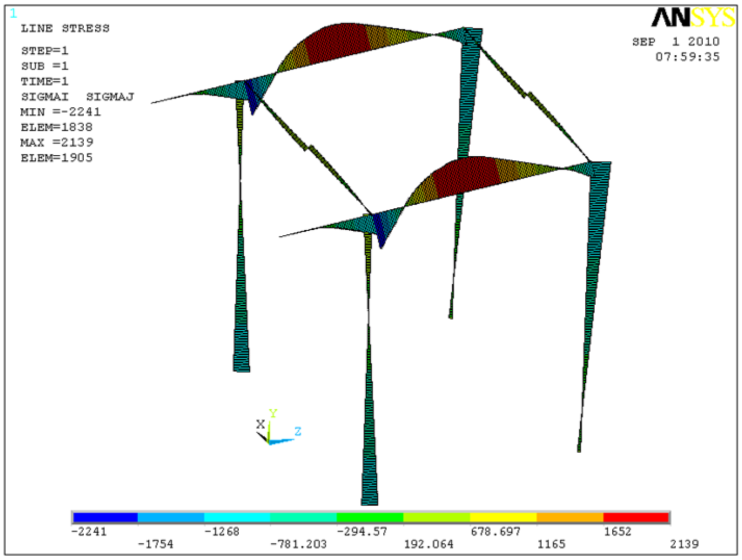
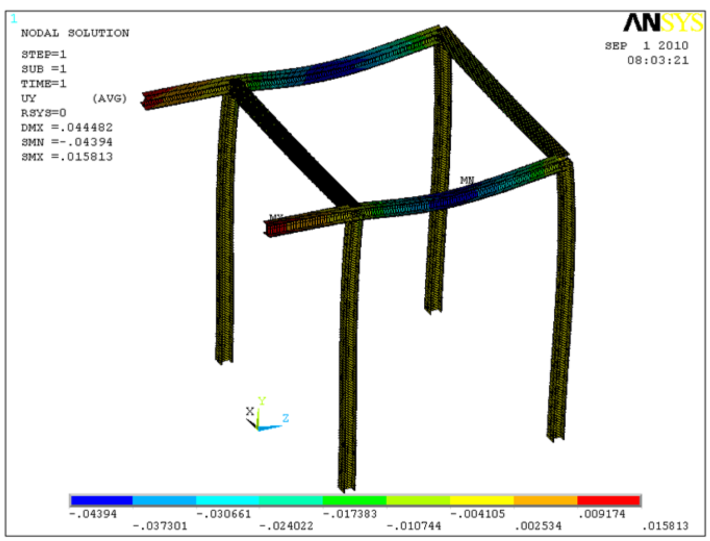


Load Case #1. Bending + Direct Stress, psi.

Figure 5 Stress plot for Load Case #1.



Load Case #1. Y Deflection, in., Plot Magnified 200x.

Figure 6 Deflection plot for Load Case #1

6.2 FEA Load Case #2 Results

Load Case #2 is the configuration with loading applied from each detector, but detectors that are able to slide out for maintenance apply their loads to just one side of the structure. In Fig. 7, the bending stress combined with the direct stress is shown in psi. The maximum combined stress (2629 psi) is in the

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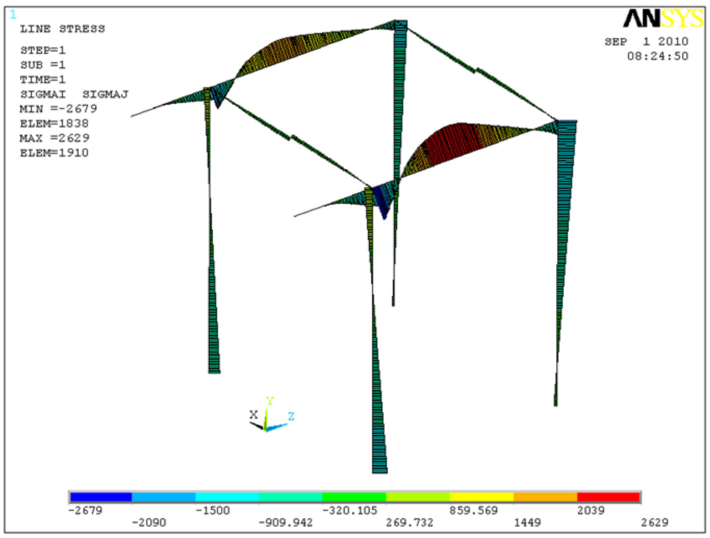
W8X31 beam located at the top on the side of the beamline where detectors are slid out for maintenance. The minimum stress is found in the same beam with a value of -2679 psi.

In Fig. 8, the deflection in the vertical direction is shown. The end of the W8X31 beam on the maintenance side deflects up by 0.018 inches. Near the midpoint of the same beam, the deflection is down by 0.050 inches.



Load Case #2. Bending + Direct Stress, psi.

Figure 7 Stress plot for Load Case #2.

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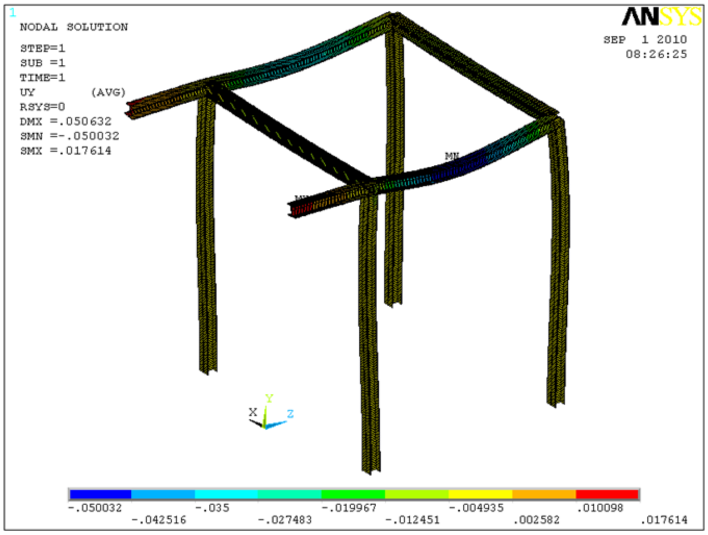

Load Case #2. Y Deflection, in., Plot Magnified 200x.

Figure 8 Deflection plot for Load Case #2.

6.3 FEA Load Case #3 Results

For a seismic event, Load Case #3has loading applied from each detector in its normal position, but a horizontal load is added. The horizontal load is 0.15 times the load of the detector split between the two support points. In Fig. 9, the bending stress combined with the direct stress is shown in psi. The maximum combined stress (1983 psi) is in the W8X31 beam located at the front top in between the two detector support beams. The minimum stress is found in the same beam with a value of -2286 psi.

In Fig. 10, the deflection in the vertical direction is shown. The end of the W8X31 beam on one side deflects up by 0.012 inches. Near the midpoint of the same beam, the deflection is down by 0.041 inches.

In Fig. 11, the deflection in the horizontal direction is shown. The highest magnitude deflection in X is 0.474 inches.

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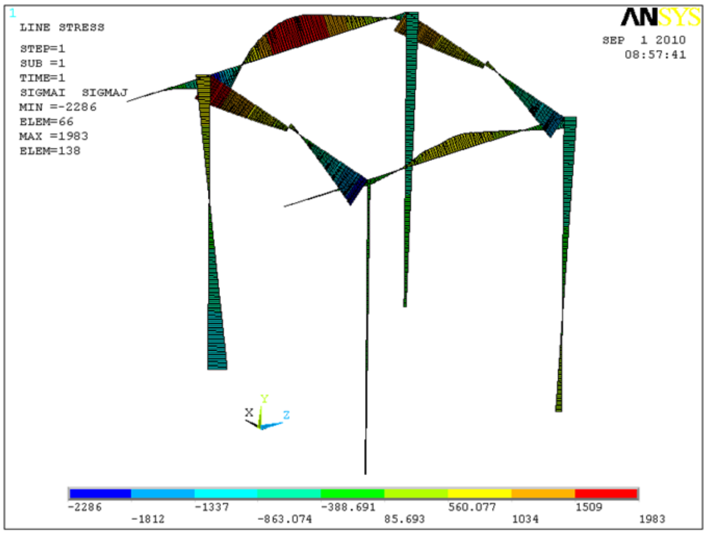

Load Case #3. Bending + Direct Stress, psi.

Figure 9 Stress plot for Load Case #3.

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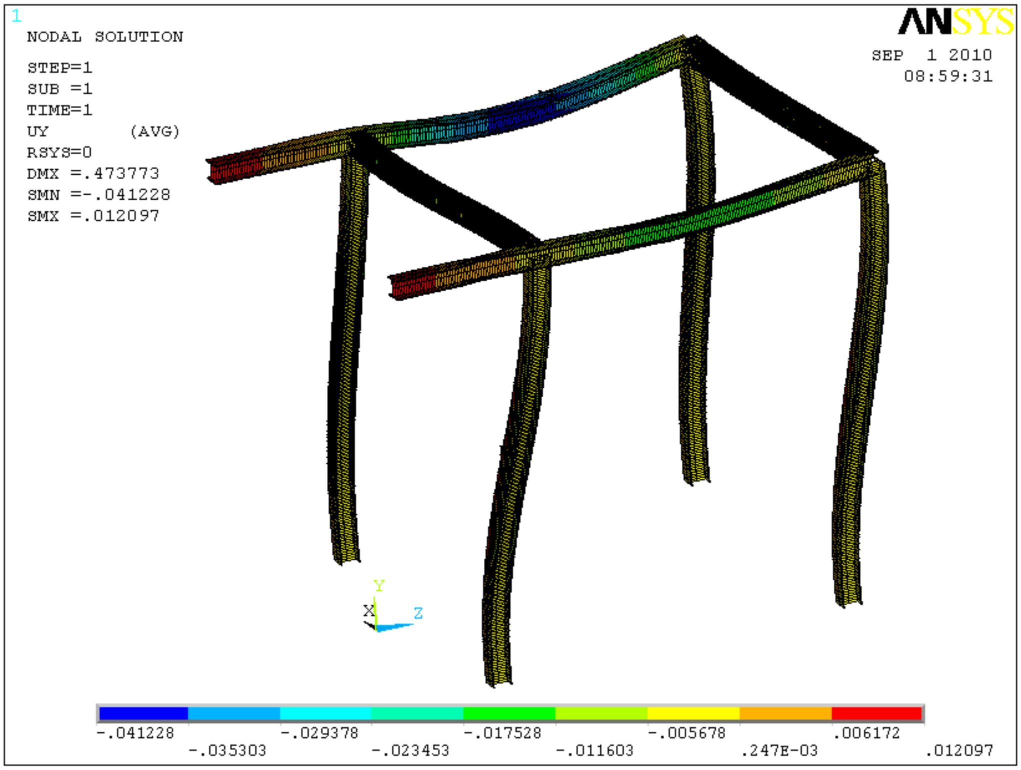

Figure 10 Vertical deflection plot for Load Case #3.

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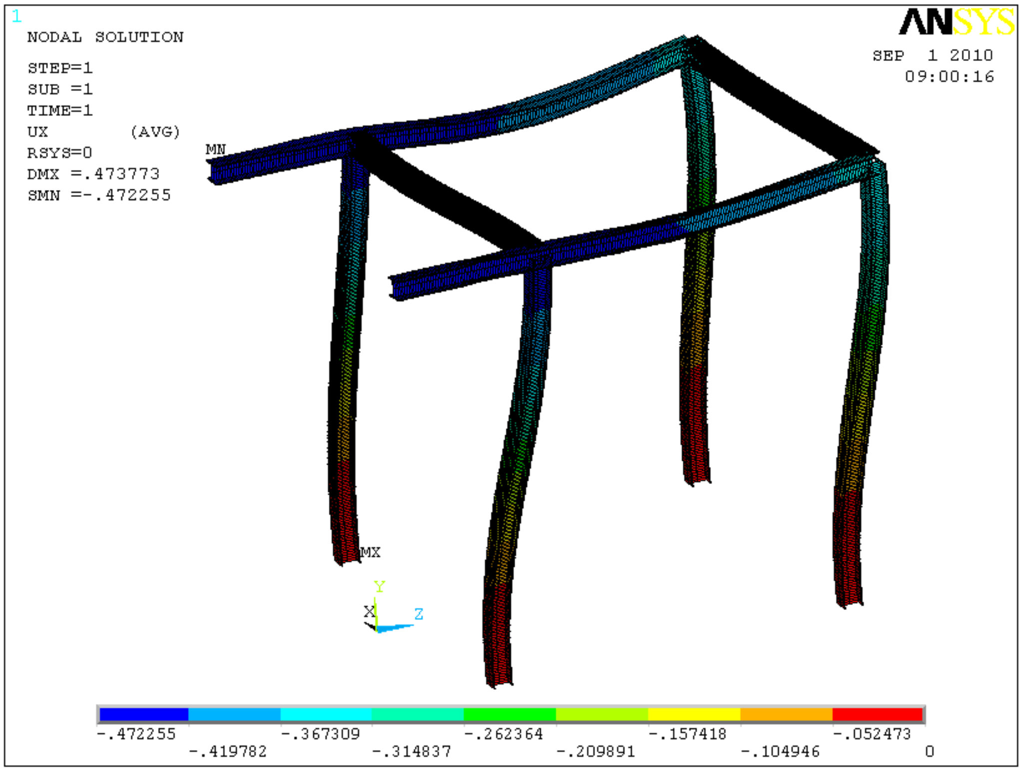

Figure 11 Horizontal deflection plot for Load Case #3.

6.4 Compressive Strength of the Column

The highest compressive force (taken from reaction force data in the FEA results) on any column from all load cases is 5344 lbf in Load Case #2. According to Section E3 of the Steel Construction Manual, the nominal compressive strength for a W8X31 column is 135,000 lbf. With the ASD safety factor of 1.67, the allowable compressive strength is 80,000 lbf. Since the load of 5344 lbf is less than the allowable, the columns are strong enough to resist buckling.

6.5 Combined flexure and compression in column

The highest combination of compressive force and bending moment is found in Load Case #3. The compressive load is 5297 lbf, and the moment is 73,773 in-lbf. Section H1 of the Steel Construction Manual gives Eqn. H1-1b, which combines the ratios of applied load to allowable load. The combination must be less than or equal to 1.0. For the case of the W8X31 column, the combination of ratios is 0.149, well below 1.0.

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7 Conclusions

7.1 The E906 Detector Support Frame design analyzed within this document under the assumptions presented in section **5** meets the requirements as set out in the acceptance criteria in section **3**.

7.2 Maintenance loading and Seismic loading do not cause any of the columns to buckle.

8 References

1. AISC Steel Construction Manual 13th Edition

9 Computer Software Specifications

ANSYS R12.1 by ANSYS, Inc.

Mathcad 14.0 M020 (14.0.2.5) by Parametric Technology Corporation

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APPENDIX 1
GENERAL CHECKING CRITERIA SHEET

CALCULATION CHECKLIST	**Yes**	**No**	**N/A**	**Comments**
1. Are analytical methods appropriate?	☐	☐	☐	
2. Are assumptions appropriate?	☐	☐	☐	
3. Is the calculation complete?	☐	☐	☐	
4. Is the calculation mathematically accurate?	☐	☐	☐	
5. Do calculation parameters comply with design criteria/dimensions?	☐	☐	☐	
6. Were input data appropriate?	☐	☐	☐	
7. Does the calculation reference or list applicable assumptions and major equation sources?	☐	☐	☐	
COMPUTER CODE CHECKLIST	**Yes**	**No**	**N/A**	**Comments**
1. Was an applicable and valid computer program used?	☐	☐	☐	
2. Are the input assumptions appropriate?	☐	☐	☐	
3. Was the input entered correctly?	☐	☐	☐	
4. Do the input results seem reasonable?	☐	☐	☐	

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APPENDIX 1
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ADDITIONAL COMMENTS		
Number	**Comment**	**Resolution**
1.		
2.		
3.		
4.		
5.		
6.		
7.		
8.		
9.		
10.		

Appendices A-L Calculation back-up

See following pages.